

IMAGE AND AUDIO DEGRADATION SIMULATOR

Cross Reference to Related Application

This claims the benefit of United States  
Provisional Application No. 60/197,101, filed April 12,  
5 2000.

Background of the Invention

This invention relates to degradation of  
electrical signals representing images and audio of film and  
television productions. More particularly, this invention  
10 relates to real-time simulation of such signal degradation.

The visual and audio quality of an original  
production, which may be a live or animated film or  
television production, or a live transmission, is rarely  
what an end-user (e.g., a television viewer or moviegoer)  
15 actually sees or hears. The visual and sound quality of an  
original production initially may be degraded because of a  
technical limitation or problem related to the electronic  
capture of the production. For example, common picture  
defects can be caused by herringbone clothing, white shirts,  
20 venetian window blinds, film grain, and excessively rapid  
camera motion. Picture and sound quality of the captured  
images and audio may then be further degraded as a result of  
post-production processing, video processing, signal  
transmission, and display at an end-user's location.  
25 Post-production processing can involve editing, color  
correction, film or tape transfers, replays, storage, and  
duplication. Signal transmission can involve compression

and decompression, analog and digital conversions, scrambling and descrambling, and noise and artifacts (i.e., stray entities that do not belong in an image). Display at an end-user's location can involve low quality picture resolution and high levels of audio distortion.

Many of these degradations can be cost-effectively corrected or compensated for by making changes to the production while that production (e.g., a particular scene) is in progress. For example, simple changes to a set (including to background, props, colors, lighting, microphone positions, wardrobe, etc.) can often eliminate the causes or at least lessen the effects of various picture and sound degradations. However, a producer (or director, cinematographer, recording engineer, etc.), who creates the film or video representation of the pictures and sounds of a film or television production, has no way of knowing, and in particular, cannot see or hear the effects of various degradations while a production is in progress. Thus, a producer has no opportunity to make typically cost-effective on-the-spot changes that could compensate for or correct various degradations that will affect the quality of the final product seen and heard by end-users.

Even "dailies," for example, which are film workprints created overnight for review in the morning to ensure that the previous day's scenes were filmed as desired, do not give a producer the opportunity to make immediate changes while those scenes are being filmed. At best, needed corrections usually involve re-assembling the cast and crew and re-shooting the scene on the next available day. Dailies are intended to be reviewed primarily for scene content and gross technical problems (e.g., inaudible dialog) while a cast, crew, and set are still available. Because dailies are unedited and unprocessed (e.g., no color correction), they are not of the same quality as that intended to be displayed to an end-user. Moreover, dailies are not intended to show the

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5 while that production is in progress.

10 substantially simultaneously while that production is in  
progress.

## Summary of the Invention

15 or television production that can be viewed substantially  
simultaneously while that production is in progress.

20 that can be viewed substantially simultaneously while that  
production is in progress.

25 production that can be reviewed substantially simultaneously  
while that production is in progress.

30 film or television production that can be viewed  
substantially simultaneously while that production is in  
progress.

35 digital signal processor, a memory, at least one algorithm

that performs a predetermined degradation on a received image or audio signal, and a display that displays images, audio, or both. The simulator simulates on the display in real time the image, audio, or both of a received signal  
5 that has been degraded in accordance with the degradation algorithm. Thus, for example, a producer can view a degradation simulation preferably substantially immediately while producing a scene to determine whether any re-shooting or production changes are needed to maintain a desired level  
10 of picture or sound quality.

The degradation simulator of the present invention preferably includes a plurality of selectable degradation algorithms, each performing a different predetermined degradation. Each algorithm can be simulated individually  
15 or in combination with others. The simulator also preferably performs recursive degradations of a selected algorithm. This allows a producer to simulate, for example, the effects of multiple signal compressions and decompressions on a video signal.

Preferably, the degradation simulator of the present invention also performs a quantitative analysis of simulated degradations to provide one or more degradation measurements that can be reviewed substantially  
20 simultaneously with production. The degradation simulator also preferably highlights on the display in real time portions of a simulation in which one or more degradations exceed a preset threshold.

Advantageously, the present invention can be used at any stage of production to simulate and evaluate the  
30 effects of degradations subsequent to that stage.

#### Brief Description of the Drawings

The above and other objects and advantages of the invention will be apparent upon consideration of the following detailed description, taken in conjunction with

the accompanying drawings, in which like reference characters refer to like parts throughout, and in which:

FIG. 1 is a simplified illustration of a representative film production process from creation to moviegoer;

FIG. 2 is a simplified illustration of a representative television production process from creation to television viewer;

FIG. 3 is a block diagram of a preferred embodiment of a degradation simulator according to the invention; and

FIG. 4 is a simplified illustration of a display screen with highlighted portions indicating unacceptable degradation according to the invention.

#### Detailed Description of the Invention

The present invention provides an image and audio degradation simulator that simulates in real time how images and audio would respectively look and sound after the electrical signals representing those images and audio have been degraded in one or more objective or subjective ways. In accordance with the present invention, degradation simulations are provided preferably substantially immediately upon receiving signals representing images and audio. Producers of film or television programming can advantageously simulate preferably one or more types of degradation on, for example, a just-completed filmed or taped scene or portion thereof to determine in real time whether any retakes or production changes are necessary -- while that scene is still in progress. Similarly, producers of live transmissions can simulate how those transmissions are being received by end-users and accordingly make any necessary production changes. Thus, a desired level of picture or sound quality can be maintained.

Moreover, the degradation simulator of the present invention can be advantageously used at any stage of a

production process (e.g., from creation to display at an end-user's location) to simulate the effects of any known subsequent degradations or any "what-if" degradations. For example, the present invention can be used with existing  
5 tapes and films to simulate the effects of a particular transmission path to an end-user. Thus, the quality of a particular link (e.g., a rental fiber circuit) that may be used for a live event can be simulated and evaluated. Similarly, producers can use the invention to simulate and  
10 evaluate a potential distributor's transmission plant before agreeing to use that distributor.

The present invention does not require that both images and audio be present concurrently, each can be degraded and simulated separately, if desired. Also, the  
15 present invention is not limited to images of a moving picture, but can also be used with still images. Furthermore, the present invention performs no correction of actual or anticipated degradations, but identifies their effects via displayed simulations and optional quantitative  
20 analyses.

Where the context permits, "displaying" includes displaying images, playing audio, or both, and "picture" includes images displayed on a movie screen, a television monitor, computer screen, or the like.

FIG. 1 illustrates a representative film  
25 production process from creation to moviegoer. "Film" refers to motion pictures that are initially shown in theaters. Film production process 100 begins with the filming of a scene 102 with one or more film cameras 104 and  
30 microphones 106. Output from camera 104 is developed into a negative 108. Negative 108 is then used to print an "interpositive" 110. An interpositive is a high quality copy of an original negative, but with positive images, and is used mostly in film labs. Interpositive 110 is then  
35 edited and processed (e.g., different scenes and different camera angles of scenes are added, sequenced, and cut; color

correction is performed; special effects, titles, and credits are added; etc.). A "video assist" 112 (i.e., a film camera optical takeoff) is often used by producers and others to assist in make editing decisions. Video  
5 assist 112 is a device that provides images seen through the lens of film camera 104, similar to that seen through the eyepiece of a camera. The edited interpositive is then printed to form an "internegative" 114. An internegative is color negative of a color transparency made for purposes of  
10 duplication.

Audio from the filmed scene is typically recorded on audio tape 116, and then edited and mixed to produce a final sound track tape 118. Editing and  
15 mixing 117 can include adding audio received from different microphones, dubbing inaudible portions, and adding background sounds. The final sound track is then usually etched onto internegative 114 and copied onto, for example, multiple compact discs (CDs) 122. The sound track may be formatted in SDDS (Sony Dynamic Digital Sound).

20 Multiple release prints 126 are then printed from internegative 114 and are typically distributed physically along with CDs 122 to theater operators. At a theater, release print 126 and CD 122 are respectively run through a film projector 128 and sound system 130 where pictures on  
25 screen 132 and sound are ultimately seen and heard by moviegoers.

Degradation of images and audio can occur throughout process 100. For example, degradation can occur at video assist 112, printing 109, editing 111,  
30 printing 124, audio editing and mixing 117, audio CD processing 120, film projector 128, sound system 130, and screen 132.

FIG. 2 illustrates a representative television production process from creation to television viewer.

35 Television productions may be videotaped or live transmissions. Television production process 200 begins



with the electronic capture of an event 202 with one or more television cameras 204 and microphones 206. A production switcher 208 controlled by an operator selects which camera output is transmitted or recorded. Similarly, an audio

5 mixer 212 is used to select and mix the audio to be transmitted or recorded. For videotaping, separate tapes are usually made of the video and audio, both of which are then typically edited, assembled, and processed at 216 into a single production tape of the complete program. This tape  
10 is then played back in a videotape player 218 which feeds a typically automated program origination switcher 220.

Switcher 220 integrates and assembles programming received from multiple sources to create the complete programming for a network or channel. Switcher 220 outputs the network or  
15 channel's complete programming to a program distribution facility 222. From there, either tapes of the programming are physically transported to various cable or satellite TV system headends 224, or the programming is transmitted to TV system headends 224 via satellite, the Internet, cable  
20 (e.g., coax or fiber optic), or any other suitable medium. During such transmission, programming is typically digitized, compressed, and possibly scrambled. From headend 224, the program is transmitted through the system plant 226 to one or more set-top boxes or televisions 228  
25 where the final product can be seen and heard by television viewers.

The live transmission path is very similar, except that instead of creating a tape that is edited and played back in a videotape player, the electrical signals output  
30 from production switcher 208 and audio mixer 212 are transmitted directly to program origination switcher 220 via satellite, cable (e.g., coax or fiber optic), the Internet, or any other suitable medium.

Similar to process 100, degradation of electrical  
35 signals representing images and audio of a television production can occur at any stage. For example, degradation

can occur at cameras 204, switcher 208, editing 216, playback 218, program origination switcher 220, program distribution 222, TV system headend 224, system plant 226, and set-top box/television 228.

5           Hybrid film/television processes that include elements of both processes 100 and 200 are also common. For example, film productions can sometimes be produced less expensively by following process 200 up to playback 218 where, instead of feeding the output of playback 218 into  
10 program origination switcher 220, the output of playback 218 is used to create an internegative 114. Similarly, when films are to be shown on television, the film's internegative 114 is processed with a "telecine" device that transfers film to videotape. That videotape is then played  
15 at playback 218 and fed into program origination switcher 220. Each of these hybrid processes incurs the same types of signal degradations as processes 100 and 200.

Although some degradation in picture and sound quality between an original production and what end-users  
20 see and hear is expected and usually imperceptible, objectionable undetected degradations can and do occur, reaching as far as the end-user. These degradations often can be corrected or compensated for had they been known or anticipated during production.

25           FIG. 3 shows a preferred embodiment of an image and audio degradation simulator 300 in accordance with the present invention. Simulator 300 includes input 302 and output 304, and preferably includes input 306 and output 308. Input 302 receives digital signals, while  
30 input 306 receives analog signals. These signals represent images and audio of preferably film, television, or hybrid productions. Output 304 provides a degraded digital signal, while output 308 provides a degraded analog signal. Preferably, simulator 300 includes a conventional  
35 analog-to-digital (A/D) converter 310 for converting analog input signals to digital signals, and a conventional

digital-to-analog (D/A) converter 312 for converting digital output signals to analog signals. The analog output signals can be used for subsequent processing, recording, or quality control logging.

Input signal sources to simulator 300 can include, for example, video assist devices, film transfers (e.g., "dailies," interpositives, internegatives, and release prints), video camera sources and production switchers, (e.g., high-quality video and RGB (red-green-blue)), microphones, audio mixing console, and analog sources (e.g., cable headend transmissions or receptions and satellite or cable (e.g., coax or fiber optic) transmissions or receptions). Digital signals received at input 302 are preferably in a serial digital component format, such as, for example, Serial Data Interconnect (SDI). SDI includes both digital video and embedded audio. Alternatively, where only analog picture, sound, or both are available, those signals can be coupled to input 306 for conversion into digital form by analog-to-digital converter 310.

Simulator 300 also includes a digital signal processor (DSP) 314, which can be a personal computer. DSP 314 includes a central processing unit (CPU) and preferably includes a RAM-storage video device, such as, for example, a ViewStore 6000 by Viewgraphics Incorporated, which has been acquired by Optibase, Inc., of San Jose, California. This device provides both a frame-buffering function and access to the CPU. The CPU performs algorithmic functions on the received image and audio signals. DSP 314 preferably includes a Pentium® III processor by Intel Corporation, of Santa Clara, California, or equivalent.

Simulator 300 further includes a memory 316 of preferably 128 megabytes. Although shown separately (primarily for illustrative purposes), memory 316 can be incorporated within DSP 314 and is preferably random access memory. Memory 316 can additionally include, or can

alternatively be, other types of suitable memory such as EEPROM, EPROM, disk, or tape. Digital signals received by DSP 314 are stored in memory 316.

5 Simulator 300 includes at least one and preferably  
a plurality of signal degradation algorithms 318 that can be  
stored in memory 316 or other suitable memory or storage  
coupled to DSP 314. Each algorithm 318 performs a  
predetermined signal degradation on a received digital  
signal. Algorithms 318 preferably perform both objective  
10 and subjective signal degradations. Preferably, they  
include the following types of film degradations: picture  
resolution loss (of preferably various degrees), "gate  
weave," and "shutter judder." Algorithms 318 preferably  
perform the following types of television film degradations:  
15 three-two pulldown motion artifacts; NTSC (National  
Television Standards Committee) "cross-chroma, reduced color  
gamut, cross-luma, and interlace 'twitter;'" PAL (phase  
alternate line) "speed variation (audio) and interlace  
'twitter.'" NTSC is a North American broadcast standard  
20 specifying, among other things, 525 lines in each complete  
video frame. PAL is a European color TV standard  
specifying, among other things, 625 lines in each complete  
video frame. Algorithms 318 also preferably perform the  
following types of television video degradations: NTSC/PAL  
25 artifacts as mentioned above, satellite FM/triangular noise  
spectrum and IF (intermediate frequency) truncation,  
analog-to-digital conversion, digital-to-analog conversion,  
VSB-AM (vestigial sideband - amplitude modulation)  
television transmission artifacts, MPEG (Moving Pictures  
30 Expert Group) signal compressions (of various bit rates and  
other parameters such as 4:2:2/4:2:0), cable television  
"cascade, 'triple-beat,' and 'composite second-order  
distortion.'" Algorithms 318 further preferably perform the  
following types of audio degradations: analog-to-digital  
35 conversion, noise reduction, sub-band coding and compression  
artifacts, and digital-to-analog conversion.

Algorithms 318 preferably include DSP digital filtering taps and memory operations that operate on the received image and audio signals. Simulator 300 can execute algorithms 318 individually, recursively, or in combination  
5 with each other, as selected by a user. Memory 316 preferably includes lookup tables for algorithms 318 to facilitate their loading and execution.

Alternatively, in another embodiment of simulator 300 in accordance with the present invention, the  
10 degradation functions performed by algorithms 318 can be performed instead by dedicated hardware in DSP 314.

Simulator 300 preferably includes an optional analytical processor 320 coupled to outputs 321 and 322 of DSP 314. Output 321 provides a digital signal received by  
15 DSP 314 before any degradations are performed on it, while output 322 provides that digital signal degraded in accordance with one or more selected algorithms 318. Analytical processor 320 analyzes received signals to provide objective measurements of the encountered signal degradation. Analytical processor 320 preferably includes a  
20 picture quality analyzer, such as, for example, a Model PQA300 by Tektronix, Inc., of Beaverton, Oregon. Picture degradation measurements preferably include signal-to-noise ratios and frequency responses. Analytical processor 320  
25 also preferably includes an audio analyzer, such as, for example, a System One or System Two series audio analyzer by Audio Precision, also of Beaverton, Oregon. An audio analyzer provides an equivalent set of objective degradation measurements. These degradation measurements are  
30 displayable on a display. Alternatively or additionally, analytical processor 320 may include its own display for displaying degradation measurements.

Simulator 300 includes display 324, which can be, for example, a 14" Model BVM-D14H1A or 20" Model BVM20E1A  
35 broadcast monitor by Sony Corporation of America, of New York, NY. Display 324 preferably displays the following

types of outputs: picture and sound as degraded by one or more selectable algorithms 318, showing what the degradations incurred along a particular film, television, or hybrid production path would do to a picture or sound track; analytical measurements of degradations incurred along a selected production path including, for example, "depth of degradation" (e.g., percent of defect), signal-to-noise ratio, root sum square (RSS) of accumulated degradations (e.g., ANSI/EIA RS-250 accumulations); and an enhanced display including, for example, a display with "zebra stripes" highlighting a particular defect (e.g., a venetian blinds picture defect).

Analytical processor 320 preferably executes software 326 that preferably uses degradations measurements and preset thresholds to provide highlighting (e.g., brightened, crosshatched, or colored areas) superimposed over portions of a display where degradation (e.g., a signal-to-noise ratio related to a picture defect) exceeds a preset threshold. For example, software 326 may provide crosshatching superimposed over a displayed portion of rapid camera motion when the picture complexity exceeds the ability of the data-rate-constrained MPEG compression decoder to faithfully reproduce the picture above a preset subjective threshold set by a system operator (e.g., the producer). To illustrate, FIG. 4 shows display 324 in which portions of a degradation simulation of a recorded or filmed scene are highlighted with crosshatching 440, indicating that the degradations in those areas exceed a preset threshold.

Described below are particular details of a simulation by simulator 300 of degradation resulting from a single pass of MPEG digital video compression and MPEG Layer 3 audio compression (e.g., MUSICAM). The simulation assumes a signal representing images and audio being transmitted via a digital cable-TV path to a typical set-top box that includes a consumer NTSC interface using VSB analog

modulation at channel 3 to a consumer-type display (e.g., a conventional television screen).

For MPEG video degradation, an algorithm 318 preferably includes a discrete cosine transform (DCT) to show the impacts of the imperfect frequency reproductions in the early stages of MPEG compression processing. Real-time inputs to algorithm 318 include the likely target MPEG bit rate and picture resolution of the transmitted picture. Other algorithms 318 (or one that performs all mentioned degradations) are also executed to simulate the MPEG decoder (e.g., filter characteristics such as group-delay), NTSC conversion (e.g., band-limited chroma, cross-color, etc.), VSB modulation (e.g., pre-shoots, filter ringing, etc.), and the consumer display (e.g., resolution impacts of screen dot-pitch, display phosphors, etc.).

Similarly, received audio signals are processed by one or more algorithms 318 that include filter tap points and filter characteristics for simulating what would be incurred in the audio sub-band companded processor (e.g., MUSICAM). Companding refers to signal compression and expansion. Real-time data inputs provide algorithms 318 with the data rate and version of the MUSICAM encoder and decoder to be simulated. Additional algorithms 318 can also be selected, preferably with a graphical user interface (GUI) preferably included in simulator 300, to include loudspeaker fidelity, amplifier distortion, or other gross or subtle degradations. The GUI permits a 'chain' of algorithms 318 to be executed for simulating different types of degradations that may be incurred along a process path (including recursive executions of particular algorithms 318 that can simulate, for example, the effects of multiple passes of MPEG encoding, A/D and D/A conversions, etc.).

Algorithms 318 preferably perform the following degradations on received signals:

Video degradations:

- MPEG-2 encoding (version: Motorola DigiCipher, TSP version 7);
- Target bit rate: 2-6 Mb/sec, variable bit rate, statistical multiplexing, medium load;
- resolution: 3/4;
- target transmission path: cable TV digital QAM (quadrature amplitude modulation), BER (bit error rate)  $> 10^{-4}$ ;
- target decoder: cable set top box, Motorola DCT-1000; and
- display: consumer TV grade dot pitch, NTSC compatible via channel 3 modulator.

Audio degradations:

- MPEG Layer 3 audio compression (version: MUSICAM; Philips version 2.0);
- Target bit rate: 128 kb/sec, network congestion: light; and
- Speaker: consumer grade 5-inch or smaller loudspeaker; 2% THD (distortion).

In a continuous stream, the digital video and audio degraded in accordance with selected algorithms 318 are provided at output 304 for display on display 324 and preferably at output 322 for quantitative analysis at analytical processor 320, as described above.

Thus it is seen that an image and audio degradation simulator is presented that simulates in real time selected degradations of images and sound of film, television, or hybrid productions either while those productions are being electronically captured or at anytime thereafter. One skilled in the art will appreciate that the present invention can be practiced by other than the described embodiments, which are presented for purposes of illustration and not of limitation, and the present invention is limited only by the claims which follow.